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NASHWAAK EXPERIMENTAL WATERSHED PROJECT

ANNUAL REPORT

1980-81

A COOPERATIVE STUDY OF THE ENVIRONMENTAL IMPACTS OF FORESTRY PRACTICES

NASHWAAK EXPERIMENTAL WATERSHED PROJECT

ANNUAL REPORT 1980-81
(for the year ending 30 April 1981)

Edited by G.R. Powell
Secretary, Technical Committee

The Nashwaak Experimental Watershed Project is a Canadian contribution to the UNESCO international program, Man and the Biosphere.

Nashwaak Experimental Watershed Project Technical Committee of the
New Brunswick Forest Research Advisory Committee

July, 1982

INFORMATION

Copies of this report are available from the Department of Natural Resources, Forest Utilization Branch, P.O. Box 6000, Fredericton, NB, E3B 5Hl. Further information about the Project or specific aspects of it may be directed through the Secretary, Technical Committee, Nashwaak Experimental Watershed Project, Department of Forest Resources, University of New Brunswick, Bag Service Number 44555, Fredericton, NB, E3B 6C2, or any of the participating agencies.

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INTRODUCTION

The Nashwaak Experimental Watershed Project, which began in 1970, is a long-term, cooperative, interagency, interdisciplinary project in which environmental and ecological consequences of selected forest management practices are being studied. The Project area lies in central New Brunswick in hilly terrain at the southern border of the New Brunswick uplands. Watersheds of three headwaters tributaries of the Nashwaak River are included in the Project (Figure 1). The watersheds range in elevation from about 200 m to 480 m. The hilltops are covered with deciduous hardwood forests. On lower slopes the hardwoods merge with the predominantly coniferous forest cover of the valleys.

The Project was designed to provide comparison between paired watersheds (control and treatment) as well as between pre-treatment and post-treatment conditions in the treated watershed. The early years were used to acquire base-level data and to calibrate the treatment watershed against the control watershed.

Two forest management practices were selected as designed treatments to be applied on complete watersheds. These were aerial application of fertilizer and commercial clearcutting. Aerial application of insecticides has been a third treatment; however, because spraying has been limited to coniferous forest, it has not affected the whole of any of the watersheds. Also, spraying has not occurred annually, so has not always been a concern. Effects on aquatic animals of some of the sprays used have been monitored in Project streams.

The first of the two designed treatments was applied in June 1975 when a fixed-wing aircraft was used to apply a nitrogen-base fertilizer to the Lake Brook Watershed (Figure 1). Effects on the stream water were small and had essentially disappeared by 1978.

The second designed treatment was a conventional, commercial clearcutting operation conducted by Valley Forest Products Ltd., under Crown Lands Act Regulations administered by the New Brunswick Department of Natural Resources. Cutting of the forest on the Narrows Mountain Watershed (except for a riparian protective strip along the mainstem of the Narrows Mountain Brook) started in May 1978 and continued until completion in March 1979.

The year, 1 May 1980 to 30 April 1981, covered by this eighth Annual Report of the Project, was the second full year after completion of the clear-cut. This report includes description of the progress of activities of the various component studies in 1980-81, and also, indications of results achieved to April 1981.

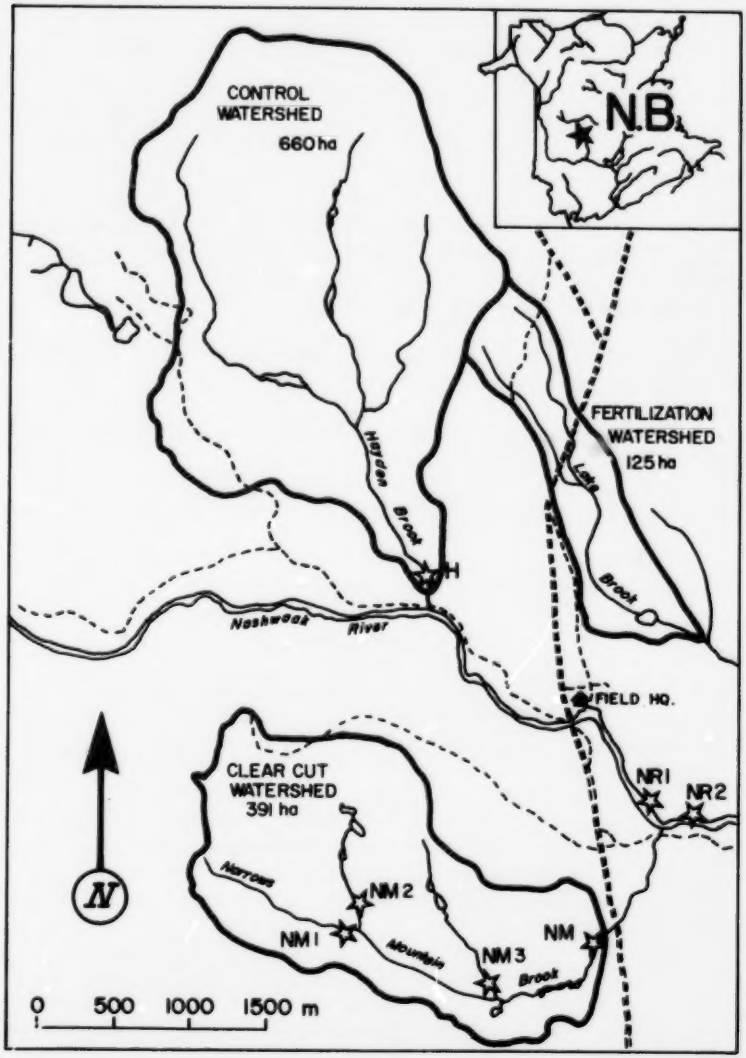

Figure 1. The location of the Nashwaak Experimental Watershed Project in New Brunswick (solid star in inset) and the locations of the three experimental watersheds. Open stars indicate the positions where stream-water quality is monitored.

OBJECTIVES

The objectives of the Nashwaak Experimental Watershed Project are:

To determine and understand the impact of certain forest management practices on environmental quality and to establish criteria for future forest management.

Within these objectives, activities are:

I. To determine the effects in forested watersheds of: (l) the prevailing clearcutting method on water yield, regime and quality, on aesthetics, on wildlife, and on forest and stream productivity; (2) fertilization with a nitrogen-source fertilizer on forest and stream productivity; and (3) spraying with insecticides on stream productivity.

II. To elucidate the physical, chemical, and biological processes and their interrelationships.

III. To establish, with the aid of modern modelling techniques, guide lines on which future forest management may be based.

IV. To demonstrate to government, industry, and the public, the impacts and processes involved.

V. To instruct students in the disciplines involved.

MANAGEMENT

The Project is managed by a Technical Committee of the New Brunswick Forest Research Advisory Committee (NBFRAC). The Technical Committee is comprised of researchers involved with the component studies, and representatives of cooperating agencies.

In 1980-81 the Technical Committee was chaired by J.S. Hoyt, New Brunswick Department of Natural Resources, and its secretary was G.R. Powell, Department of Forest Resources, University of New Brunswick. The Committee met in June to review progress of component studies and to consider future work, and in October to finalize plans for seminars to be given on the early results of the clearcutting treatment. The chairman reported to NBFRAC twice during the year, as required.

COMPONENT STUDIES

The component studies of the Project, their status in 1980-81, and the principal investigators are listed in the following.

Topographic survey (completed) — G. Gloss, Dept. of Surveying Engineering, U.N.B., Fredericton.

Stream gauging (continuing) — D.K. Randall, Water Survey of Canada, Fredericton.

Climate and water balance (continuing) — R.B.B. Dickison and D.A. Daugharty, Dept. of Forest Resources, U.N.B., Fredericton.

Soils, their identification and mapping, surface conditions, and hydraulic properties (continuing) — H.H. Krause, H.B. King and P.A. Arp, Dept. of Forest Resources, U.N.B., Fredericton.

Precipitation and stream-water chemistry; nutrient cycling (continuing) — H.H. Krause, H.B. King and P.A. Arp, Dept. of Forest Resources, U.N.B., Fredericton.

Forest vegetation: composition, growth and regrowth (continuing) — G.R. Powell, Dept. of Forest Resources, U.N.B., Fredericton.

Forest litterfall and seedfall (continuing) — G.R. Powell, Dept. of Forest Resources, U.N.B., Fredericton.

Effectiveness of riparian vegetation; physical attributes of streams (continuing but inactive in 1980-81) — H. van Groenewoud, Maritimes Forest Research Centre, C.F.S., Fredericton.

Allochthonous organic stream detritus, retention, and decomposition (continuing) — N.K. Kaushik, Dept. of Environmental Biology, University of Guelph, Ontario, J.H. Meating, Fredericton (now Great Lakes Forest Research Centre, C.F.S., Sault Ste. Marie, ON), and D.C. Eidt, Maritimes Forest Research Centre, C.F.S., Fredericton.

Aquatic plant populations and communities (continuing) — A.R.A. Taylor, Dept. of Biology, U.N.B., Fredericton, and G.B. Bacon, New Brunswick Research and Productivity Council, Fredericton.

Stream invertebrates, populations, and communities (continuing) — D.C. Eidt, Maritimes Forest Research Centre, C.F.S., Fredericton.

Fish: populations, migrations, and growth (continuing) — J.D. Martin, Biological Station, Fisheries and Marine Service, St. Andrews, NB.

Modelling (continuing but inactive in 1980-81) — all participants, coordinated by H. van Groenewoud, Maritimes Forest Research Centre, C.F.S., Fredericton.

TREATMENTS

Fertilization of Lake Brook Watershed

The fertilization treatment consisted of an aerial application of ammonium nitrate over the Lake Brook Watershed in June, 1975. The treatment, monitoring of fertilizer distribution, subsequent nitrogen movements, and biological effects in the stream were described in previous Annual Reports. Most effects had become negligible by 1977 or 1978 and sampling in Lake Brook has been minimal since then.

Insecticide Applications

No areas of the Project watersheds were sprayed from the air with insecticides in 1980, so no work related to insecticide applications was undertaken.

Clearcutting of Narrows Mountain Watershed

The clearcutting treatment constitutes the major treatment of the Project. The treatment was applied in 1978-79 when, from May to March, the forest on Narrows Mountain Watershed was clearcut in a conventional, commercial tree-harvesting operation. Monitoring of effects began as the cutting progressed. Continued assessment of effects constituted the main Project activity in 1980-81.

PROGRESS OF COMPONENT STUDIES

Stream Gauging (D.K. Randall)

The stream gauging program was continued by Water Survey of Canada during 1980. During periodic visits to each of the five gauging stations, discharge measurements were obtained to check the stage-discharge relationships. The results are summarized in Table 1.

Table 1. Numbers of discharge measurements made during 1980 at five stations and consequent effects on stage-discharge relationships.

Station	Number of discharge measurements	Effect on stage-discharge relationship
Hayden Brook	5	Confirmed existing relationship.
Narrows Mountain Brook Main Station	6	Maintained existing relationship despite changes resulting from headpond filling.
Narrows Mountain Brook Branch 1	8	Confirmed existing relationship.
Narrows Mountain Brook Branch 2	5	Confirmed existing relationship. Obtained record high measurement.
Narrows Mountain Brook Branch 3	7	Shift corrections were required while using existing relationship because of sediment buildup in headpond. Obtained record high measurement.

Measurements at the three branch stations on Narrows Mountain Brook were discontinued as of December 31, 1980. The original purpose for these stations stipulated a short period of operation to determine the distribution of flow and the runoff time response from the three branches. It was felt that with about five years of record from the stations, their purpose had been fulfilled.

Some data were collected on water temperatures at the main stations on Narrows Mountain Brook and Hayden Brook. With the conversion of the Hayden Brook station equipment to metric in late September 1980, the thermograph record could not be extracted from the chart. The thermograph record at the Narrows Mountain Brook station was interrupted when a Winnipeg Pressure water-level recorder was installed in late October 1980. This unit was installed to replace the existing water-level recorder which was required for use elsewhere in the Province.

The automatic sediment sampler at Narrows Mountain Brook did not operate well during the spring, and subsequently was removed from service. Most of the suspended-sediment-data computations were based on manual samples obtained by staff of Water Survey of Canada and by other Project participants.

At the station on Branch 3 of Narrows Mountain Brook, sediment accumulation in the headpond above the timber weir persisted as a continual problem. On each visit to the station, the accumulated sand was manually removed down to a suitable level.

Climate and Water Balance (R.B.B. Dickison and D.A. Daugharty)

Collection of hydrometeorological data continued through 1980 without modification to programmes outlined in calibration-period reports.

General climate and water balance

It was cooler and drier in 1980 than in 1979. The mean annual temperature was 3.4°C and total precipitation was 1252 mm. Both values were close to the calculated normal values for the Project headquarters station.

Water-balance data for the period of record using measured data from the precipitation networks in the two watersheds, are given in Table 2. Evapo-transpiration (ET) is calculated from the difference between precipitation (P) and stream discharge (Q), after accounting for the change in storage(ΔS). The change in storage is determined solely from the year-end differences in snow depth at the headquarters station, hence it is assumed to be the same for both watersheds.

An increase of 65 mm (Figure 2) in the discharge for 1980 was indicated as being due to the clearcutting treatment, using the predictive equation,

$$Q_{NMB} = 15.0 + 0.897\, Q_{HB} + 0.836(P_{HB} - P_{NMB})$$

$$r^2 = 0.986 \quad \text{s.e.} = 34.0 \text{ mm}$$

developed by Dickison, Daugharty and Randall (1981 Proc. 5th Can. Hydrotechnical Conf., Fredericton, NB, May 1981, pp. 59-71). In this, the subscripts NMB and HB refer, respectively,

Table 2. Annual water balances for Hayden and Narrows Mountain Watersheds for 1971-1980.

	Year	Hayden					Narrows Mountain				
		P (mm)	Q (mm)	ΔS (mm)	ET (mm)	Q/P	P (mm)	Q (mm)	ΔS (mm)	ET (mm)	Q/P
	1971	1034	597								
	1972	1478	934	+20	454	0.66	1423	854	+20	549	0.60
	1973	1567	1374	-89	282	0.88	1595	1276	-89	408	0.80
Calibration	1974	1367	956	+28	383	0.70	1351	906	+28	416	0.67
period	1975	1180	662	+ 8	510	0.56	1211	629	+ 8	574	0.52
	1976	1670	1157	-17	530	0.69	1618	991	-17	644	0.61
	1977	1372	897	+14	461	0.65	1365	770	+14	581	0.56
Year of treatment	1978	1124	672	+33	419	0.60	1095	604	+33	458	0.55
Post-	1979	1638	1233	-59	464	0.75	1475	1125	-59	409	0.76
treatment	1980	1304	792	+20	490	0.61	1224	725	+20	479	0.59

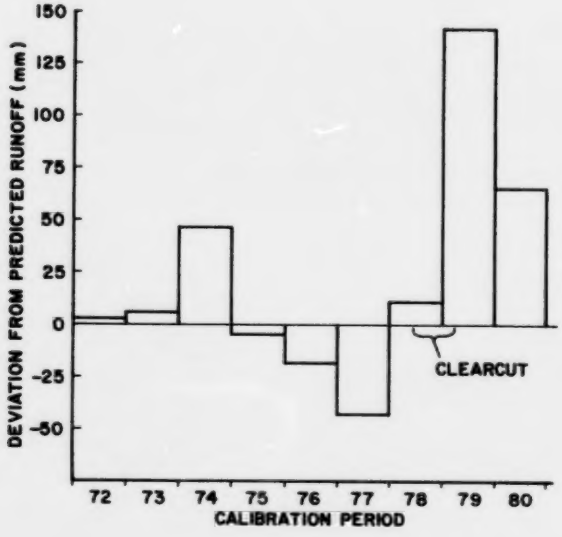

Figure 2. Deviations from predicted runoff from Narrows Mountain Basin for each year since the beginning of the calibration period.

to Narrows Mountain Brook and Hayden Brook. It is now believed that this preliminary estimate of the treatment effect was too high, because of a change in the catch efficiency of the precipitation gauges during snowfall. The gauges in Narrows Mountain Brook Watershed are no longer protected from wind by the surrounding forest and appear to be consistently measuring less winter precipitation than those in Hayden Brook Watershed. This catch-efficiency problem will be studied carefully to allow a revised estimate of the effect of treatment on the annual water balance. Until this study has been completed the current estimates should be considered preliminary.

Peak flows

It was expected from the results of other similar experiments that the treatment would affect peak flows. To develop a prediction equation, 27 events were selected for analysis during the calibration period, eliminating cases where discontinuous rainfall produced complex hydrographs, and a few other cases where brief periodic recorder malfunction seemed to have obscured peak flows. An event was considered to have occurred if the increase above base flow reached at least 0.14 m^3s^{-1}. Using peak flow on the control water shed ($q_{p_{HB}}$) and difference in storm precipitation($\triangle P$) in mm as independent variables, the following relationship was obtained (Dickison, Daugharty and Randall, ibid.):

$$q_{p_{NMB}} = 0.0025 + 0.543\, q_{p_{HB}}\, 0.069\triangle P$$

$$r^2 = 0.945;\ \text{s.e.} = 0.0709\ m^3s^{-1}$$

In 1979, the year following treatment, eight events fitted the criteria established for calibration. The relationship between predicted and actual peak plows determined by simple linear regression was

$$q_{p_{NMB}} = 0.03 + 1.59\hat{q}_{p_{NMB}}$$

Inasmuch as the intercept value was nearly zero, the apparent effect of the treatment was an increase of 59% in summer peak flows. The relationship is shown in Figure 3. For 1980, a similar analysis of ten storms showed an increase of 38% indicating some recovery in peak-flow responses.

For runoff volume analysis, eight of these 1980 storms met the criteria for inclusion (discrete storm events with flows exceeding 0.28 m^3s^{-1} from the control basin). Treatment effects were estimated using the prediction equation given in the 1979-80 Annual Report and positive effects were indicated for all but the storm of May 19-20 (Table 3). This apparent discrepancy was caused by a greater soil moisture deficit in the clearcut area at this season resulting from the advanced snowmelt. Hayden Brook was at the peak of its snowmelt response in late April, as will be discussed below, and its antecedent soil-moisture condition for the May 19-20 event was therefore not adequately representated by the precipitation.

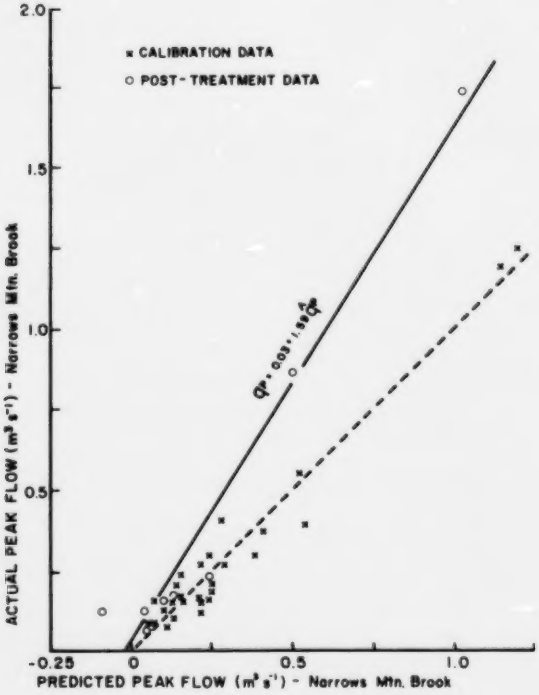

Figure 3. Comparison between predicted and actual peak flows (after base-flow separation) for summer-season (June-October) events on Narrows Mountain Brook before (dashed line) and after (solid line) clearcutting.

Table 3. Runoff volumes for 1980 storms from Hayden and Narrows Mountain Watersheds showing estimated before-treatment volumes ($\hat{Q}$) and treatment effect (ΔQ).

Date	Hayden			Narrows Mountain				
	Q (mm)	P (mm)	Q/P	Q (mm)	P (mm)	Q/P	$\hat{Q}$ (mm)	ΔQ (mm)
19-20 May	1.26	16.8	0.075	1.19	17.7	0.067	1.40	-0.21
08-09 Jun	1.68	25.1	0.067	2.06	29.6	0.069	1.71	+0.35
05-07 Jul	1.74	24.7	0.070	2.44	25.2	0.097	1.76	+0.68
11-13 Jul	3.37	37.1	0.096	3.09	30.2	0.102	2.97	+0.12
14-15 Sep	3.29	35.5	0.093	4.16	39.6	0.105	2.91	+1.25
04-05 Oct	5.40	35.5	0.152	7.20	35.5	0.203	4.48	+2.72
11-13 Oct	3.83	30.4	0.126	5.16	30.4	0.170	3.31	+1.85
26-27 Oct	3.11	25.4	0.122	2.78	25.4	0.109	2.78	0.0

Figure 4 shows the relationships among solar radiation, net all-wave, and reflected solar radiation before and after treatment, for two typical cloudless days before and after clearcutting. Total net radiation was reduced after treatment indicating that energy previously used in evapotranspiration was being converted to other energy forms — primarily sensible heat. Reflected solar radiation was also decreased by about one percent of incoming solar radiation as a result of a change in the albedo of the surface. The change in net radiation produced by the clearcutting exhibited a diurnal pattern clearly dominated by surface temperatures. Increased out-going long-wave radiation from the warmer surface during daylight caused a reduction in net radiation which was partly compensated for by a net gain (less negative) at night when the outgoing long-wave radiation was reduced because of lower surface temperatures.

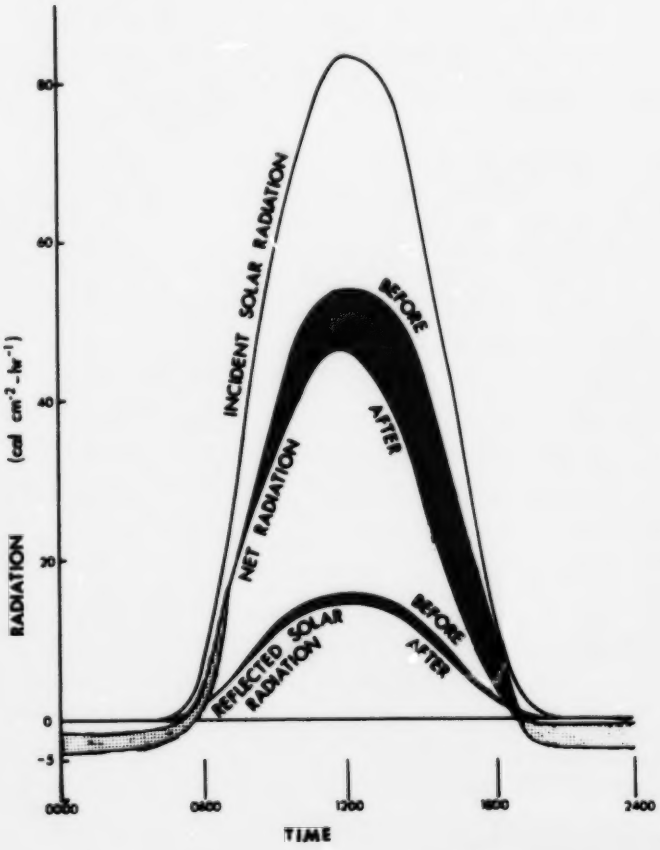

Figure 4. Average daily distribution of hourly totals of incoming solar, net all-wave, and reflected solar radiation for two similar July days before and after cutting.

Snow survey and snowmelt

The winter seasons of both 1979-80 and 1980-81 were somewhat peculiar with respect to snowpack accumulation and ablation. In 1979-80 (Figure 5A) the snow pack was the smallest of any year since the beginning of the Project with a maximum pack of about two-thirds of what is considered normal, and there was no significant accumulation before mid-February. Snow cover in 1980-81 (Figure 5B) developed similarly to that of most other years until February when a major mild spell (daytime maximum temperatures as high as 13°C) reduced the pack by more than half.

The abnormalities of the 1980 and 1981 seasons seriously hamper determination of the relationships between snowcover and topography and the altered forest condition. However, within the clearcut area a drastic reversal of the snow depth/elevation relationship was evident (Table 4), with snow depth/elevation gradients at maximum pack of -6.1 and -10.7 cm/100 m (decreasing snow depth with increasing elevation) in 1980 and 1981, respectively. The 1980 gradient for Hayden Brook was close to that found in both basins for normal seasons before treatment — that is, a gain of snow depth with increasing elevation.

Table 4. Statistics from linear regression of snow depth against elevation at the time of maximum snow cover.

Date of beginning of survey	Number of observations	Mean depth (cm)	r^2	a (cm)	b (cm/100 m)	b/SD_{300} (%/100 m)
	--- Hayden Brook Basin ---					
20 Mar 80	51	52.5	.254**	23.7	9.4	18.1
24 Mar 81	49	80.3	.001	78.0	0.7	0.9
	--- Narrows Mountain Brook Basin ---					
17 Mar 80	40	52.5	.086*	70.7	-6.1	-11.6
24 Mar 81	40	61.7	.076	93.8	-10.3	-17.3

* Significant at the 0.10 level
** Significant at the 0.01 level

The snowmelt contribution to spring peakflows has been examined for the years since treatment and significant desynchronization between the two basins has been found. This is illustrated by Figure 6 where it can be noted that snowmelt began to affect discharge from the clearcut on April 13 while the forested basin did not respond significantly until April 21. By April 27, the forested basin was discharging snowmelt at a rate increasing daily but the clearcut basin had ceased to respond having lost its snow cover. This figure was not continued beyond April 28 because of the intervention of a rainfall event that confused the pure snowmelt contribution.

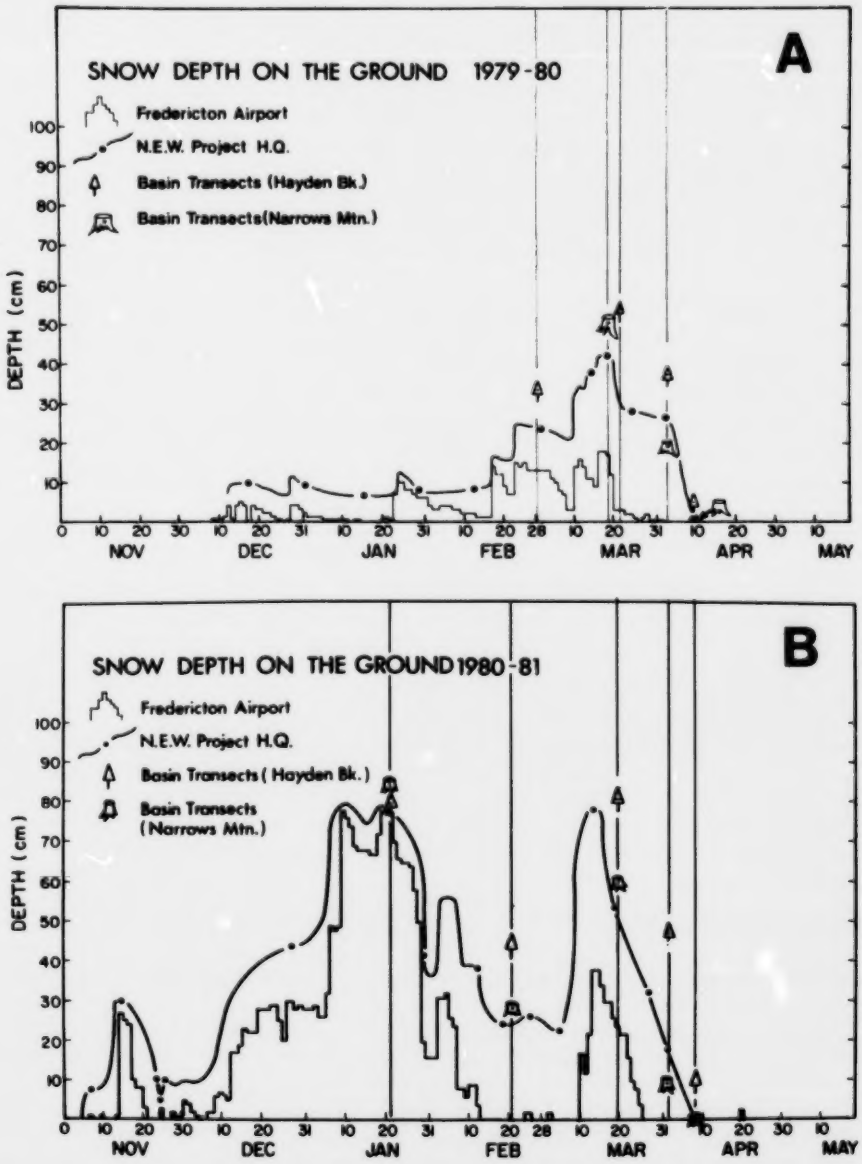

Figure 5. Comparative snow depths on the ground at the Fredericton airport, N.E.W. Project headquarters station, and clearcut and control watersheds, A. 1979-80, B. 1980-81.

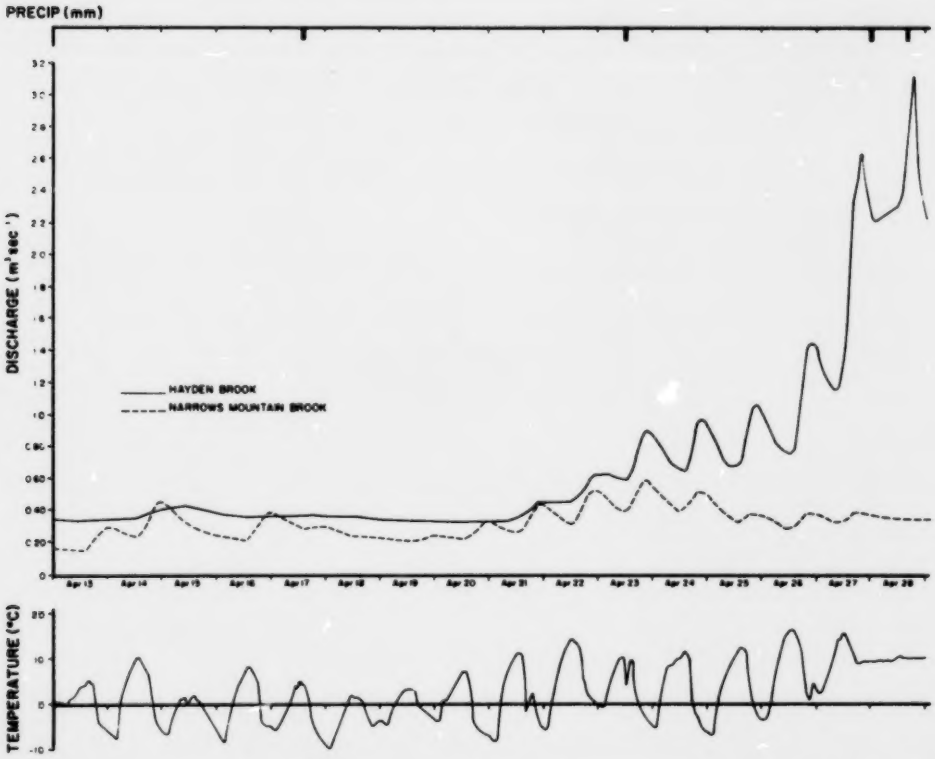

Figure 6. Hayden Brook and Narrows Mountain Brook continuous discharge and associated air temperatures during the rain-free period of active snowmelt, April 1979.

Precipitation Chemistry, Throughfall Quantity and Composition (H.H. Krause)

Precipitation has been sampled in the Project area since 1973 and analyzed to determine acid pollutant and nutrient loads. During 1980, 41 samples were collected in Hayden Brook Watershed (H6) and analyzed as described previously (Annual Reports 1979/80, p.14; 1978/79, p.13; and 1977/78, p.14). The median values for 1980 (Table 5) showed lower than normal (5-year period, 1973/77) pH, sodium (Na) and calcium (Ca) contents and higher than normal nitrogen (N) contents. Sulphur (S) and NO_3 loading corresponded to annual deposition rates of 0.84 and 0.24 g m^{-2}, respectively. The S deposition rate was higher than the rate given previously for a location in northern New Brunswick, but lower than deposition rates reported for portions of Nova Scotia, and much lower than in Southern Ontario, the St. Lawrence River Valley and the industrial areas of the northeastern United States (Galloway and Welpdale, 1980, Atmospheric Environment 14: 409-417).

Table 5. Acid pollutant and nutrient concentrations in precipitation samples from the Nashwaak Experimental Watershed Area. Concentrations are given in mg/litre except for P concentrations which are in µg/litre.

	1980			1973-77		
	Median	Range		Median	Range	
pH	4.26	3.82-	5.67	4.60	3.72-	4.60
Na	0.10	0.01-	1.45	0.20	<0.01-	1.89
K	0.08	0.03-	0.85	0.11	<0.01-	1.26
Ca	0.13	<0.01-	0.44	0.33	<0.01-	4.60
Mg	0.04	0.01-	0.14	0.06	<0.01-	0.78
NO_3-N	0.20	<0.01-	0.55	0.17	<0.01-	1.72
NH_4-N	0.15	0.00-	0.60	0.11	<0.01-	2.62
Org-N	0.18	0.03-	1.92	0.19	0.02-	1.05
P	10.00	<0.01-	387.50	14.4	1.00-	175.00
Cl	0.38	0.16-	2.00	--	--	--
SO_4-S	0.69	0.21-	2.35	--	--	--

Observations from the Project area, dating back to 1973, show some annual variation in precipitation chemistry, but no definite trends are discernible.

Throughfall (canopy wash) was sampled under a hardwood stand during three major storms in the early, mid and late season of 1980. The method of sampling was described in the Annual Report of 1977/78, p.15. The throughfall samples were analyzed as precipitation samples. To date, throughfall from seven storms has been sampled under hardwood and softwood stands. The project is continuing. When sufficient data have been collected, an attempt will be made to establish a model for nutrient input to soil by canopy wash, and to quantify possible relationships between acid-pollutant level and nutrient leaching from foliage.

Effect of Clearcutting on Stream-Water Quality and Nutrient Balance (H.H. Krause)

Suspended sediment

In previous Annual Reports (1979/80, p.19 and 1978/79, p.16-18) it was shown that there were appreciable sediment loads in Narrows Mountain Brook, especially in its branch streams, during the year of cutting (1978). In the first year following the cut, sediment loads resurged to high levels in one of the branch streams during the spring freshets, and recurred at all sampling stations during major summer storms and periods of prolonged precipitation in late fall.

In 1980, the second year after the cut, the number of storms producing a sediment load above control diminished, but the stream still carried appreciable amounts of sediment during extreme events. This is evidenced by the maximum concentrations of suspended sediment given in Table 6 for Narrows Mountain Brook and its branch streams. It should be recalled that the values given were derived from composite samples for 2-week time intervals.

Table 6. Medians (m) and ranges of pH, and nutrient and suspended sediment concentrations determined for Hayden Brook, and Narrows Mountain Brook mainstem (NM), and Branches 1, 2 and 3 (NM1, NM2, and NM3, Figure 1) during 1980. Nutrient and suspended sediment concentrations are given in mg/litre except for P concentrations which are in g/litre.

	Hayden Brook		Narrows Mountain Brook									
			NM				NM1		NM2		NM3	
			Calculated[a]		Observed		observed		observed		observed	
	m	Range	m	Range	m	Range	m	Range	m	Range	m	Range
pH	6.89	6.48- 7.73	6.93	6.71- 7.35	6.89	6.36- 7.76	6.89	6.57- 7.65	7.11	6.86- 7.74	7.15	6.58- 7.96
Na	1.28	0.90- 2.38	1.19	0.89- 2.06	1.28	0.88- 1.59	1.43	1.10- 1.84	1.19	0.86- 1.48	1.27	0.97- 2.40
K	0.26	0.20- 0.54	0.30	0.24- 0.53	0.52	0.34- 0.84	0.59	0.28- 0.83	0.46	0.27- 0.72	0.52	0.24- 0.74
Ca	4.49	2.53- 5.50	5.60	3.30- 6.77	5.73	4.18- 8.50	5.06	3.56- 6.63	8.44	5.63-14.50	6.56	4.90- 7.50
Mg	0.69	0.50- 0.88	0.91	0.70- 1.12	0.94	0.73- 1.36	1.05	0.85- 1.45	1.15	0.86- 1.98	1.04	0.88- 1.41
NH_4-N	0.00	0.00- 0.14	0.02	0.02- 0.10	0.05	0.00- 0.15	0.05	0.00- 0.51	0.05	0.00- 0.14	0.09	0.00- 0.23
NO_3-N	0.10	0.00- 0.28	0.08	0.02- 0.20	0.71	0.23- 1.62	1.47	0.55- 2.40	0.76	0.09- 2.13	0.69	0.15- 1.48
Org-N	0.18	0.01- 0.51	0.17	0.08- 0.35	0.30	0.04- 0.65	0.29	0.03- 0.63	0.21	0.01- 0.71	0.21	0.04- 0.50
P	5.60	2.30-12.30	7.89	7.03- 9.63	9.60	1.20-29.70	8.35	1.50-61.50	5.70	0.10-43.80	7.50	2.00-41.50
Susp. sed.	0.78	0.01- 2.42	0.95	0.62- 1.64	1.09	0.14-19.80	0.58	0.00- 3.38	0.58	0.00-13.29	1.63	0.00-14.36

[a]From concurrent observations in Hayden Brook and the pre-treatment relationship between Hayden and Narrows Mountain Brook.

Dissolved solids

The effect of clearcutting on dissolved solids in Narrows Mountain Brook was most obvious for NO_3-N (Table 6). Peak concentrations were observed early and late in the year (Figure 7). The effect of the cut on NO_3-N in the stream was also pronounced during the period of the 1980 spring freshets.

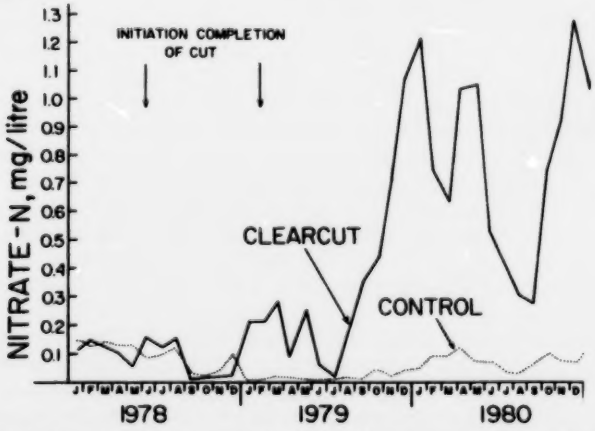

Figure 7. Effect of clearcutting on monthly nitrate-N concentrations in Narrows Mountain Brook at the main sampling station (NM). Control concentrations were obtained from concurrent observations in Hayden Brook and the pre-treatment relationships between Hayden and Narrows Mountain Brooks.

Nitrate levels varied with location in Narrows Mountain Brook. The highest concentrations were recorded at NM1 in Branch 1 (Table 6, Figure 8). This branch drains the portion of the watershed with the largest hardwood component and a predominance of moderately sloping and well-drained soils.

Median concentrations of Na, K, Ca and Mg in the treatment stream were slightly increased above control, and the median pH was somewhat below control during 1980 (Table 6 — NM, calculated and observed values). This, presumably, is the result of increased nitrification and nitrate movement in the cut watershed.

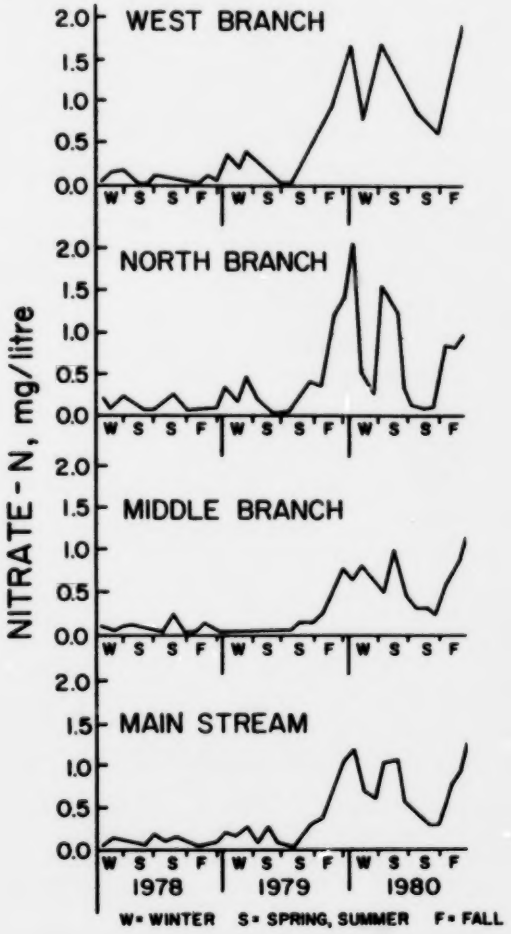

Figure 8. Concentrations of nitrate-N in Branches 1 (West), 2 (North), and 3 (Middle) (NM1, NM2 and NM3 in Figure 1), and at the main sampling station (NM) of Narrows Mountain Brook, 1978-80. Values are seasonal averages.

The noticeably increased concentrations of phosphorus (P) at the main sampling station (NM) of Narrows Mountain Brook (Table 6) apparently reflects the recurring, above-normal sediment loads in the stream.

The above observations indicate that the effect of clearcutting on dissolved N in Narrows Mountain Brook is more prominent than in a number of experimentally cut watersheds elsewhere in North America, but much below the effect of the conventional clearcut in the Hubbard Brook Watershed of New Hampshire.

Nutrient balance

The current year (1980) had slightly lower than normal precipitation. The annual net losses of Na, K, Ca and Mg from the control watershed were therefore close to the mean annual net losses for the calibration period, 1973-77 (Annual Report 1977/78, p.16). As in the previous year, the N balance for the control watershed was positive because of high N gains from precipitation (Table 7).

Table 7. Nutrient additions to, and losses from, Hayden and Narrows Mountain Watersheds during 1980. Additions are bulk deposition from the atmosphere.

Element	Additions	Losses			Net losses(-) or gains(+)		
		Hayden	Narrows Mountain		Hayden	Narrows Mountain	
			Calculated[a]	Observed		Calculated[a]	Observed
		kg/ha					
Na	2.48	10.56	9.49	8.54	- 8.08	- 7.01	- 6.06
K	1.71	2.32	2.57	4.28	- 0.61	- 0.86	- 2.58
Ca	1.47	31.13	36.87	38.44	-29.66	-35.40	-36.96
Mg	0.49	5.11	6.06	6.62	- 4.62	- 5.58	- 6.13
N	6.77	2.78	2.53	9.31	+ 3.99	+ 4.24	- 2.54
P	0.48	0.05	0.06	0.10	+ 0.43	+ 0.42	+ 0.38

[a]From concurrent observations in Hayden Brook and pre-treatment relationships between Hayden and Narrows Mountain Brook.

Clearcutting in Narrows Mountain Watershed resulted in a N net loss of 2.54 kg/ha for 1980. Without the cut, a positive nitrogen balance of 4.42 kg/ha would have been expected (calculated value). Thus, the N budget was reduced by 6.78 kg/ha in the clearcut watershed during 1980. In the previous year, a reduction of 3.88 kg/ha had occurred.

The increased N loss was paralleled by slightly increased net losses of K, Ca and Mg (compare calculated and observed net losses in Table 7). Although these losses are small if measured in absolute amounts, they represent an appreciable relative change for K. According to Table 7, the net loss of K was increased threefold in the clearcut watershed during 1980.

Net losses of N from Narrows Mountain Watershed have shown an increasing trend since initiation of the clearcut. Evaluation of the overall effect of this treatment on nutrient budgets requires, therefore, several years of additional observation.

Forest Vegetation: Composition, Growth and Regrowth (G.R. Powell)

Regrowth following the clearcut was measured in the forest growth plots in 1979 (see previous Annual Report), and is scheduled for re-measurement in 1981 and 1983. Thus data on the various types of regrowth will be obtained for the first, third and fifth growing season following cutting, permitting analysis of the dynamics of early revegetation. In 1980, therefore, field work on the vegetation was not required, but observations in the cut-over area showed (1) that sprout growth from cut stumps, particularly of sugar maple *(Acer saccharum* Marsh.), continued to be prominent, and (2) that raspberry (*Rubus strigosus* Michx.) was becoming a major part of the revegetation.

In the laboratory, work was centred on organizing data for processing and on producing summaries of the various data files.

Forest Litterfall and Seedfall (G.R. Powell)

Litterfall and seedfall accumulations in traps in 15 forest-growth plots designated as litterfall-collection plots, and in 5 streamside plots were collected on schedules similar to those of the years before the clearcut treatment. Collection of litterfall from one of the eight non-streamside plots in the treatment watershed was discontinued because a local rise in the water table caused the litterfall traps to be submerged for much of the year.

As in 1979, molestation of traps in 1980 in the cut-over portion of the treatment watershed was minimal (2 of 530 possible collections). Overall, molestation was less than in previous years, with only 20 of the 1200 possible collections not being made.

Physical analysis of the collected litterfall progressed well. By the end of the reporting period, all separations of components in the collected samples of litterfall had been completed, as had most of the oven-drying and weighing of those components.

For the five years before the clearcut treatment, the mean annual total litterfall averaged 358 g/m^2 and 351 g/m^2 in the control and treatment watersheds, respectively. Comparable values for hardwood litterfall were 288 g/m^2 and 234 g/m^2, and for softwood litterfall were 48 g/m^2 and 84 g/m^2. In the first full year after the clearcut treatment (1979), litterfall of each type was less (and in 1980 more) in the control watershed than it had averaged before the cut (Figure 9). With removal of most of the tree cover in the treatment watershed, the litterfall there was, naturally, much reduced. The total 1979 litterfall was 28% of the mean annual litterfall before the cut. Within this, litterfall of hardwood origin was 16%, and of softwood origin was 56% of amounts before the cut (Figure 9). The difference corresponded (1) with differences in residual trees and saplings (eastern white cedar (*Thuja occidentalis* L.) was not cut and large residual trees of that species were common at lower elevations), and (2) with extended fall of leaves from softwood slash. This latter was less of a factor in 1980 when softwood litterfall in the cutover area was 22% of the pre-cut mean value (Figure 9). It is expected that the rapid revegetation that is occurring on the cutover watershed will result in increasing litterfall in future years.

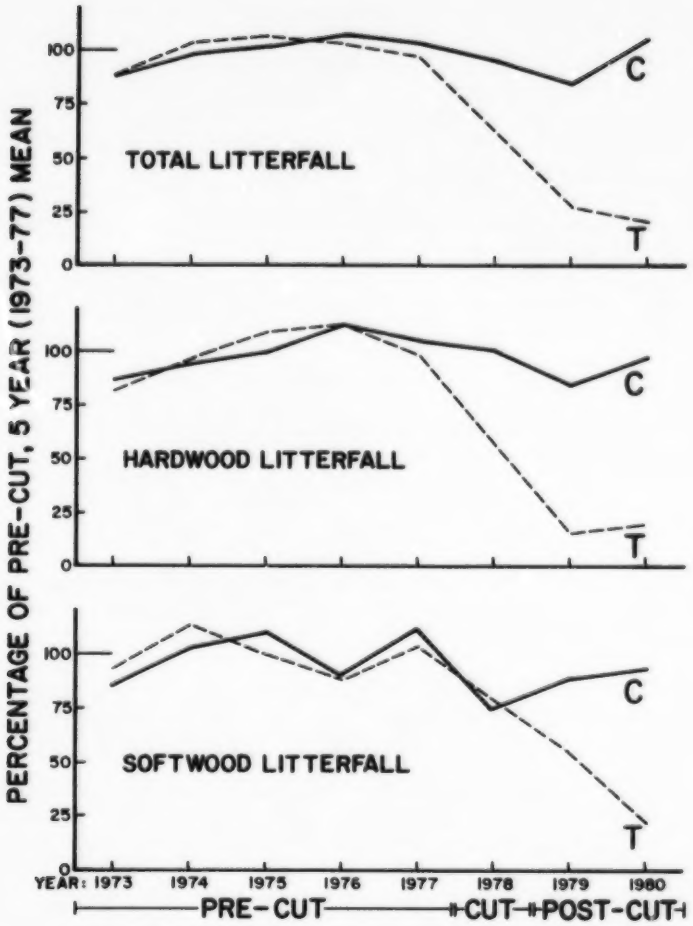

Figure 9. Annual total, hardwood, and softwood litterfall for the control (C) and the treatment (T) watersheds, expressed as percentages of the mean value for the five pre-cut years (1973 to 1977).

During the five years before the clearcut treatment, seedfall from the various species was extremely variable (Table 8). The greatest seedfall was from yellow birch which had heavy seed crops in 1974 and 1976 and moderate crops in the other years. This suggestion of heavy biennial bearing was not substantiated by the low yellow birch seedfall, in the control watershed, in 1978. The value for 1979 was, however, reasonably high (Table 8). Eastern white cedar produced a heavy seed crop in 1976; indeed, most species bore more seed in 1976 than in other years. The two major hardwoods of the watershed, beech and sugar maple, bore some seeds in each year (Table 8). The seedfall of these species in the control watershed in 1978 suggests that some

Table 8. Mean seedfall[a] (number per m^2), by species, in eight plots in the control (C) and in the treatment (T) watersheds from each of the five annual crops before treatment began in 1978, and in eight plots in the control watershed in 1978 and 1979.

	1973		1974		1975		1976		1977		1978	1979
Species	C	T	C	T	C	T	C	T	C	T	C	C
Yellow birch *Betula alleghaniensis* Brit.	166	629	1834	1846	23	94	2576	3322	188	1361	6	1135
White birch *Betula papyrifera* Marsh.	37	2	542	5	12	8	782	87	384	13	5	622
Speckled alder *Alnus rugosa* (DuRoi) Spreng.	0	15	0	0	0	21	1	32	7	18	0	0
Beech *Fagus grandifolia* Ehrh.	14	9	13	19	28	17	65	40	9	6	32	11
Sugar maple *Acer saccharum* Marsh.	3	15	72	70	10	10	215	201	4	5	33	18
Red maple *Acer rubrum* L.	9	1	104	20	21	54	29	41	88	67	104	27
Striped maple *Acer pensylvanicum* L.	148	102	129	26	79	96	315	161	82	57	101	57
Ashes *Fraxinus* sp.	0	2	0	21	0	1	0	4	0	1	0	0
Spruces *Picea* sp.	9	118	13	95	1	13	133	108	155	107	18	114
Balsam fir *Abies balsamea* (L.) Mill.	31	28	32	90	0	0	37	55	1	1	5	75
Hemlock *Tsuga canadensis* (L.) Carr.	0	0	0	2	0	0	1	54	0	0	1	1
Eastern white cedar *Thuja occidentalis* L.	11	82	54	390	12	33	489	1978	0	0	1	1

[a] Because the means are derived from plots in diverse stand types in which species distribution is varied, they provide only an indication of the nature of the seed years for the different species.

fresh seed of beech and sugar maple may have been available in that year in the treatment watershed in areas where hardwood cover was not cut until September or later. Because red maple sheds its seeds in June, reasonable quantities of seeds of that species would have been available to germinate in 1978 in the treatment watershed, mostly before cutting took place. The data for spruce and balsam fir (Table 8) suggest that little seed of those species would have been available in the treatment watershed in the year of cutting, so the chances for new germinants of those species would have been small.

The data on which Table 8 is based will provide useful information on the seed production of the different tree species in mixed forest conditions. They will also be of value in interpreting regeneration as the results of the revegetation study become available.

Allochthonous Detritus in Streams (J.H. Meating and D.C. Eidt)

Disks of leaf tissue and packs of whole leaves of six species of tree were incubated in Narrows Mountain Brook at the lower end of the riparian strip, and in Hayden Brook, to monitor decompositon for a second post-treatment season. The decomposition process followed predictable patterns based on the experience of previous years. No losses of data occurred due to ice, spates or other events, and good data were obtained. In the next year, the data will be carefully analysed to determine if there are differences that can be attributed to the clearcutting treatment. Cursory examination of the data suggests that there are not.

Stream Invertebrates (D.C. Eidt)

Sampling of stream invertebrates continued through the summer of 1980, but at a somewhat reduced rate. The time necessary to analyse the samples is considerable and with a very large backlog, it was decided to take the minimum number of samples necessary to establish the nature of the populations. Thus, effort was concentrated on the minipots, on the surbers, and on the transects by means of which the proportions of stream-bed types were determined. Emergence cages were operated at two of the three sites on each stream where they were operated before the clearcut. All sampling ceased early in September when seasonal help was no longer available. Henceforth, all effort will be concentrated on the anlaysis of samples. No more samples will be collected because the manpower will not be available to analyse them. It is expected that the anlaysis of samples will be finished by 1982, at which time analysis of data will begin.

Fish (J.D. Martin)

Fish sampling studies by electrofishing in July, 1980, showed numbers of most species to be within the range of previous years (Table 9). Exceptions were eels in Hayden Brook and brook trout in Narrows Mountain Brook (riparian-strip site) which showed a slight increase and decrease, respectively. Populations in 1980 were similar to 1979 for Hayden Brook and Narrows Mountain Brook (riparian-strip site) while Narrows Mountain Brook (clearcut site) had a 15% increase in brook trout and a 25% decrease in sculpins over the previous years. Fish numbers in 1980 were also generally lower than the 1972-78 pre-treatment means except for brook trout in Narrows Mountain Brook (clearcut site), salmon in Narrows Mountain brook (riparian-strip site), and eels in Hayden Brook, which were all slightly higher.

Means of pre- and post-treatment fish biomass showed decreases of 6% for Narrows Mountain Brook (clearcut site) and 10% for Narrows Mountain Brook (riparian-strip site) after cutting. However, Hayden Brook (control) showed a decrease of 28% in fish biomass for the same period indicating that clearcutting was probably not the reason for biomass decrease in the experimental stream.

Recruitment of young-of-the-year brook trout within the clearcut area of Narrows Mountain Brook in 1980 was 35 fish per 100 m^2. The mean number of brook trout fry in this area before cutting was 25 fish per 100 m^2 (standard deviation = 13).

Two seasons of post-cut sampling data suggest that effects of clearcutting on fish in this particular watershed have been relatively subtle when compared to the magnitude of fluctuations of wild fish populations under natural environmental conditions.

Table 9. Midsummer (July) population densities of fish species for nine consecutive years at three locations in Hayden and Narrows Mountain Brooks.

Stretch and area fished	Fish species[a]	Estimated number/100 m^2								
		1972	1973	1974	1975	1976	1977	1978	1979	1980
Hayden	Brook trout	25.7	19.0	11.9	22.2	26.5	15.1	23.0	15.9	17.3
1422 m^2	Atlantic salmon	0.5	2.3	3.7	5.9	2.2	1.8	1.8	1.1	0.3
	Eels	2.7	4.1	3.2	4.7	3.9	2.4	6.0	6.9	8.1
Narrows Mountain	Brook trout	19.2	16.2	12.8	11.9	12.1	8.4	9.0	7.8	6.4
riparian-strip	Atlantic salmon	0.8	8.2	2.0	18.9	14.7	18.4	13.5	11.6	11.5
site	Eels	6.6	9.1	0.8	5.1	3.3	1.6	1.2	1.1	1.2
498 m^2 1972-4	Blacknose dace	5.9	4.6	0.7	0.7	7.1	6.4	0.9	3.1	1.7
742 m^2 1975-6	Creek chub	0	0.6	0.2	0.1	0	0	0	0	0
645 m^2 1977+	Slimy sculpin	0	0	0.2	0.4	1.2	0.2	0.8	0.3	0.8
Narrows Mountain	Brook trout	-	-	68.3	97.8	67.3	46.4	55.5	54.8	69.2
clearcut site	Slimy sculpin	-	-	28.7	41.3	28.3	13.7	26.4	32.4	21.4
407 m^2	Eels	-	-	0.2	0	0.5	0	0.5	2.9	1.2

[a]Brook trout (*Salvelinus fontinalis*), Atlantic salmon (*Salmo salar*), eels (*Anguilla rostrata*), blacknose dace (*Rhynichthys atratulus*), creek chub (*Semotilus atromaculatus*), slimy sculpin (*Cottus cognatus*).

EDUCATION AND EXTENSION

The most significant public relations events of 1980-81 were two full-day public symposia held on the UNB Campus, one on 17 December 1980 and the other on 26 February 1981. Their purpose was to present early results of the clearcutting experiment to government, industry, and media representatives. On 2 March 1981, an abbreviated presentation was made to the New Brunswick Legistlature's Select Committee on Renewable Resources.

In May 1980 Drs. Eidt and van Groenewoud conducted a group of nine persons from the New Brunswick Federation of Field Naturalists through the Project area. The main emphasis was insect, other animal, and plant life, especially in the streams.

Prof. R.B.B. Dickison presented two special seminars on hydrometeorological studies. The first was in December 1980 to the New Brunswick Chapter, Canadian Meteorological and Oceanographic Society; and the second was in March 1981 in the UNB Forestry Seminar series.

As in previous years, many students in Forestry participated in field "labs" at the Nashwaak Project Site and performed practical exercises using data and equipment of the Project.

Undergraduate theses in Forestry and one in Civil Engineering (listed below) were prepared to the mutual benefit of the student and the Project. Several students in Forestry and Science were employed in a variety of disciplines for various periods both in the field and in laboratories, the experience being an important adjunct to their training.

Undergraduate theses:

Bewick, D.A. 1981. The effect on growing season peak flows of harvesting a small forested watershed. B.Sc.F. Thesis, Univ. New Brunswick, Fredericton, NB, 37 p.

Endall, C.P. 1981. First-season assessment of post-logging conditions and regeneration on the Narrows Mountain Watershed following clearcutting in 1978. B.Sc.F. Thesis, Univ. New Brunswick, Fredericton, NB, 62 p.

Hicks, F.G. 1981. APL programs for unit hydrograph analysis and their application to the Narrows Mountain Brook watershed. B.Sc.E. Thesis, Univ. New Brunswick, Fredericton, NB, 114 p.

Udit, B. 1981. Rates of forest litter decomposition and mineralization as affected by clear-cutting. B.Sc.F. Thesis, Univ. New Brunswick, Fredericton, NB, 64 p.

PUBLICATIONS

Dickison, R.B.B. and D.A. Daugharty. 1980. Effects of forest cover and topography on snow cover in central New Brunswick, Canada. Pp. 329-335 *in* Proc. Helsinki Symp., The influence of man on the hydrological regime with special reference to representative experimental basins, IAHS Publ. No. 130.

Martin, J.D. 1980. Natural fish populations in two streams of the Nashwaak Experimental Watershed. Can. Tech. Rep. Fish. Aquat. Sci. 982, iii + 17 p.

Powell, G.R. 1980. "Fall" in the forest. U.N.B. For. Focus 5(4), Fac. For., Univ. New Brunswick, 4 p.